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Electrical and structural characterization of Sn-DLC thin films for piezoresistive sensors

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Abstract

Sn-DLC thin films were deposited by a dual magnetron sputtering system using a fixed DC power applied to a C target and a variable DC or HiPIMS power supply applied to a Sn target. Scanning electron microscopy (SEM) images showed the presence of larger Sn clusters on films deposited using HiPIMS compared with those deposited using DC power supply. The small resistivity of HiPIMS films can be related with the large Sn cluster and the elevated number of sp^2 type bonding.

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Keywords: DLC; Sn-DLC; HiPIMS; sputtering; co-sputtering

1. Introduction

Diamond-like carbon (DLC) have interesting properties, such as chemical inertness, low roughness and high hardness [1], that make this material useful for several applications, including Micro-Electro-Mechanical Systems (MEMS), where it can be used as piezoresistive material for pressure sensors [2]. However, the intrinsic DLC have high electric resistivity and low thermal stability [1,3], that can be enhanced by adding metal into DLC matrix [1,3-4].

The reduction mechanism of DLC resistivity have been discussed by several authors as caused by three reasons: i) the electronic doping by metallic elements [5]; ii) the increase of the size of metal clusters and decrease of their

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distances [6]; iii) the increase in the amount of sp^2 bonds of the DLC films (graphitization) [5, 7-8].

The DLC thin films used for MEMS applications are usually deposited by DCMS (Direct Current Magnetron Sputtering) or RFMS (Radio Frequency Magnetron Sputtering), but a very promising technique, High Power Impulse Magnetron Sputtering (HiPIMS), has recently been studied due to its pulsed magnetron sputtering with low duty cycle [9] that has capability to generate extremely dense plasma with high ionization ratio [10]. Some of the results of this high rate of gas ionization are the improvement in adhesion, hardness and homogeneity of the films and the higher ionization rate of sputtered metallic materials [11].

In this work, a co-magnetron sputtering system was used to produce Sn-DLC thin films. DC and HiPIMS power supplies were applied to Sn target, in order to observe the influence of the waveform and power on the film characteristics.

2. Experimental

Sn-DLC thin films were deposited by a co-magnetron sputtering system on silicon substrates, using C and Sn targets. DC and HiPIMS power supplies were used to sputter the Sn target, varying the average power applied from 15 to 30W. The carbon target was sputtered by a DC power supply fixed at 150W. The argon flow was maintained at 20sccm, the work pressure at 5mTorr and the target-substrate distance at 180mm.

Raman spectroscopy was performed using a Microscope Alpha-300R to determine the bonds present in the films. The morphology was analyzed by scanning electron microscopy using a NovaNano SEM-400. A Jandel-RM3000 four points probe was used to determine the sample resistivitiesand the cantilever method [12] to determine the sample piezoresistivities.

3. Results

The Raman spectroscopy shows typical D and G peaks of DLC. After the spectra deconvolution, it was possible to observe a reduction in ID/IG ratio with the increase of the electric power applied to the Sn target, as can be seen in Figure 1. The linear decrease in the ID/IG ratio indicates that the insertion of Sn in DLC matrix promotes the graphitization of the films, i.e., induces an increase in the amount of sp^2 bonds.

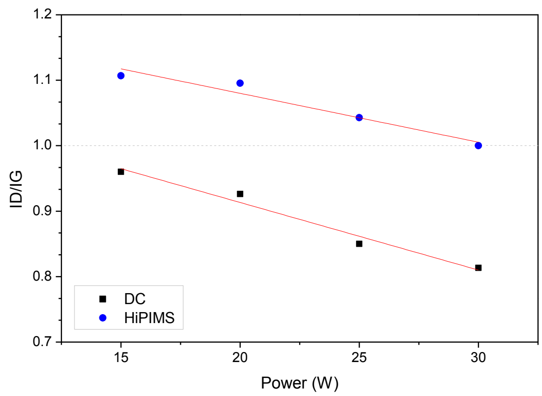

Fig. 1. ID/IG ratio as function of power applied to Sn target.

The SEM images (Figure 2) show that the presence of metal clusters in DLC matrix increases with the increase of power applied to metal target. It can also be observed that HiPIMS power supply promotes the formation of bigger clusters with smaller distance between the clusters, when compared to DC one, which can be associated to the high rate of gas ionization caused by this power supply.

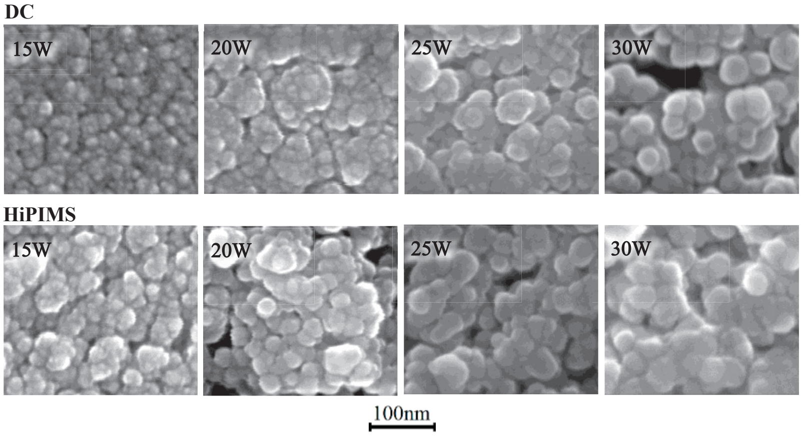

Fig. 2: SEM micrographs of the DC and HiPIMS deposited thin films (500.000X magnification).

The four points probe results (showed in Figure 3) indicated a reduction in resistivity with the rise in the power applied to the metallic target. Comparing the film resistivities and the ID/IG ratio, we can verify a relation between them, indication that the reduction of the resistivity occurs due to the graphitization of the film induced by the metal clusters.

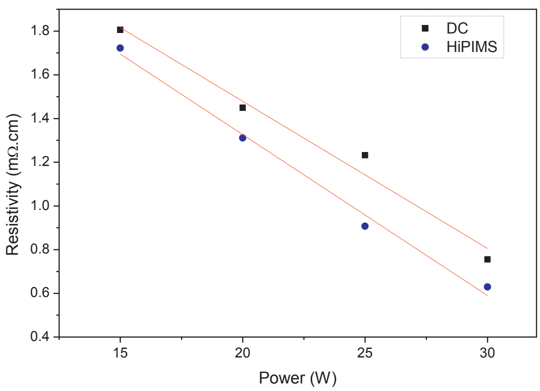

Fig. 3: Resistivity as function of the applied power to the Sn target. The lines represent the linear fit.

The piezoresistive analyses (showed in Figure 4) indicate an increase in the resistance variation and a rise of the slope with the power for both DC and HiPIMS depositions. This phenomenon is probably caused by the decrease of resistivity of the films. The piezoresistivity in Me-DLC thin films comes from the fact that the pressure causes a reduction in the distances between the metal/metal carbide clusters. The HiPIMS samples presented small distances between the Sn clusters, therefore, resistance variation was smaller than the films growth using DC power supply.

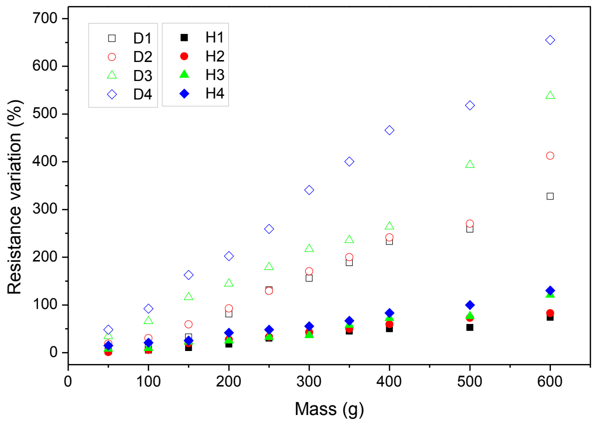

Fig. 4: Resistance variation as function of the applied load on the cantilever for all deposited films.

4. Conclusion

The samples deposited with higher power on the Sn target showed to be better for applications in piezoresistive sensors, because they presented lower resistivity and higher resistance variation. Both DC and HIPIMS power supplies presented similar results, however, the first one presented larger resistance variation while the second one presented lower values of resistivity.

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